SHEAR AND STRAIN FINESTRUCTURE NEAR A SEAMOUNT

Eric Kunze
School of Oceanography, University of Washington
Box 357940
Seattle, WA 98105-7940
phone: (206)-543-8467 fax: (206)-543-6073 e-mail: kunze@ocean.washington.edu
Award #: N00014-94-1-0038

LONG-TERM GOAL

My interests are in oceanic phenomena ranging from the meso- to the microscale that contribute to mixing and stirring, with a focus on their interactions. These include internal waves, potential-vorticity-carrying finestructure, turbulence, double diffusion, bottom topography and surface forcing. Parameterization of the impact of "subgridscale" processes on larger scales.

SCIENTIFIC OBJECTIVES

The recent focus has been on understanding how topography interacts with the meso- and finescale flow fields in the surrounding ocean.

APPROACH

Profile measurements collected over the summit and flanks of Fieberling Seamount during the ONR-sponsored Topographic Interactions program have been analysed to isolate an anticyclonic vortex, diurnal shear and intensified turbulence co-existing in a 200-m thick layer overlying the summit plain. This work has been in collaboration with Drs. John Toole, Ray Schmitt and Kurt Polzin (WHOI). Analytic theory has been developed to explain the diurnal shear layer as a vortex-trapped near-inertial near-inertial internal wave (with Dr. Emmanuel Boss (UW)), and to explore the effect of vertical geostrophic shear on propagation of near-inertial internal waves. Geometric arguments have been used to
estimate the local and global impact of bottom-intensified mixing in the stratified ocean.

WORK COMPLETED

The Fieberling Seamount observations have been written up in two papers. Fine- and microstructure measurements on the flanks have been published (Toole et al. 1997). My major effort is in a paper in press describing measurements on the summit plain (Kunze and Toole 1997). Minor revisions are underway on a submitted paper describing the vortex-trapped internal wave model and comparing it to observations over Fieberling Seamount and in a Gulf Stream warm-core ring (Kunze and Boss 1997). This model corrects an earlier model (Appendix of Kunze et al. 1995). Results were also presented at the 1997 TOS meeting in Seattle.

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A WKB theory for near-inertial wave propagation in vertical geostrophic shear was presented at the 1997 Liege Colloquium on Ocean Mixing Revisited. I am revising a submitted paper describing these results (Kunze 1997).

This August, velocity, temperature and salinity profiles were collected along the continental slope outside Monterey Bay to examine cross-slope internal wave propagation. This data is being processed.

RESULTS

The fortnightly cycling in the strengths of the vortex, diurnal shear and turbulence over Fieberling's summit plain point to their all being driven by the astronomical diurnal tides. Thus, tidal rectification is responsible for generating a vortex cap at a deep ocean seamount.
The proximity of the seamount to the diurnal turning latitude, and the -0.5f vorticity of the vortex cap allow the diurnal shear to be a vortex-trapped near-inertial wave (Kunze and Boss 1997) rather than a seamount-trapped topographic wave as modelled by Brink (1989; 1990). This was deduced from the phase relations between velocity and density (Fig. 1). Seamount-trapped waves are observed at Cobb Seamount well poleward of the diurnal turning latitude (Codiga and Eriksen 1997). The improved vortex-trapped wave model does a better job of describing the radial structure of the observed diurnal oscillations
in Fieberling's vortex cap (Fig. 2). Turbulence over the seamount summit was 100 times more intense than that typically found in the main pycnocline (Ledwell et al. 1993).

Vertical shear induces a frequency minimum at finite wavenumber for internal waves propagating to the right of the flow (Mooers 1975). Waves with lower wavenumber have vertical phase and group velocities in the same direction. This allows a hysteresis-loop standing wave where the up- and downgoing components have different vertical wavelengths, group velocities and amplitudes.

IMPACT/APPLICATION

Doming over seamount summits cannot necessarily be interpreted as evidence of a Taylor cap (e.g., Roden 1987). Tidal rectification apparently plays a much larger role in the deep ocean than previously thought, particularly in the absence of well-defined impinging geostrophic flow. Since tidal forcing is more ubiquitous than steady flows, it may prevail over Taylor-Proudman generation of vortices atop seamounts.

If the levels of intensified turbulence found above the summit and flanks of Fieberling Seamount are typical, then there is insufficient topography in contact with main pycnocline isopycnals to bring the basin-average diapycnal diffusivity up to 1 cm^2/s. This supports ideal thermocline notions for creation of the upper pycnocline (Luyten, Pedlosky and Stommel 1983) as opposed to a purely vertical balance (Munk 1966). However, in abyssal waters below 4000-m depth, the shrinking basins and more numerous penetrating ridges could elevate basin-average diapycnal diffusivities above 1 cm^2/s.

Thus, measurements at Fieberling Seamount have raised doubts about traditional interpretations of vortex caps and bottom-intensified subinertial fluctuations, and addressed the role of boundary mixing for the global ocean.

Traditionally, upward phase propagation has been interpreted as signifying downward energy propagation. The possibility of near-inertial waves with vertical phase and group velocities in the same direction could confuse interpretation in vertical geostrophic shear.

TRANSITIONS

Work related to abyssal and topographically-intensified turbulent mixing was cited in Science by Kerr (1997).

RELATED PROJECTS

Experience gained with the Fieberling Seamount data analysis will be used to analyse velocity, temperature and salinity profile data collected along the 1000- and 1500-m isobaths of the continental slope outside Monterey Bay, California during August 1997, and along the New England continental slope during spring 1998 as part of LIWI. These ONR-funded data sets will be used to quantify the cross-slope internal wave energy-flux available for turbulent mixing on the shelf.

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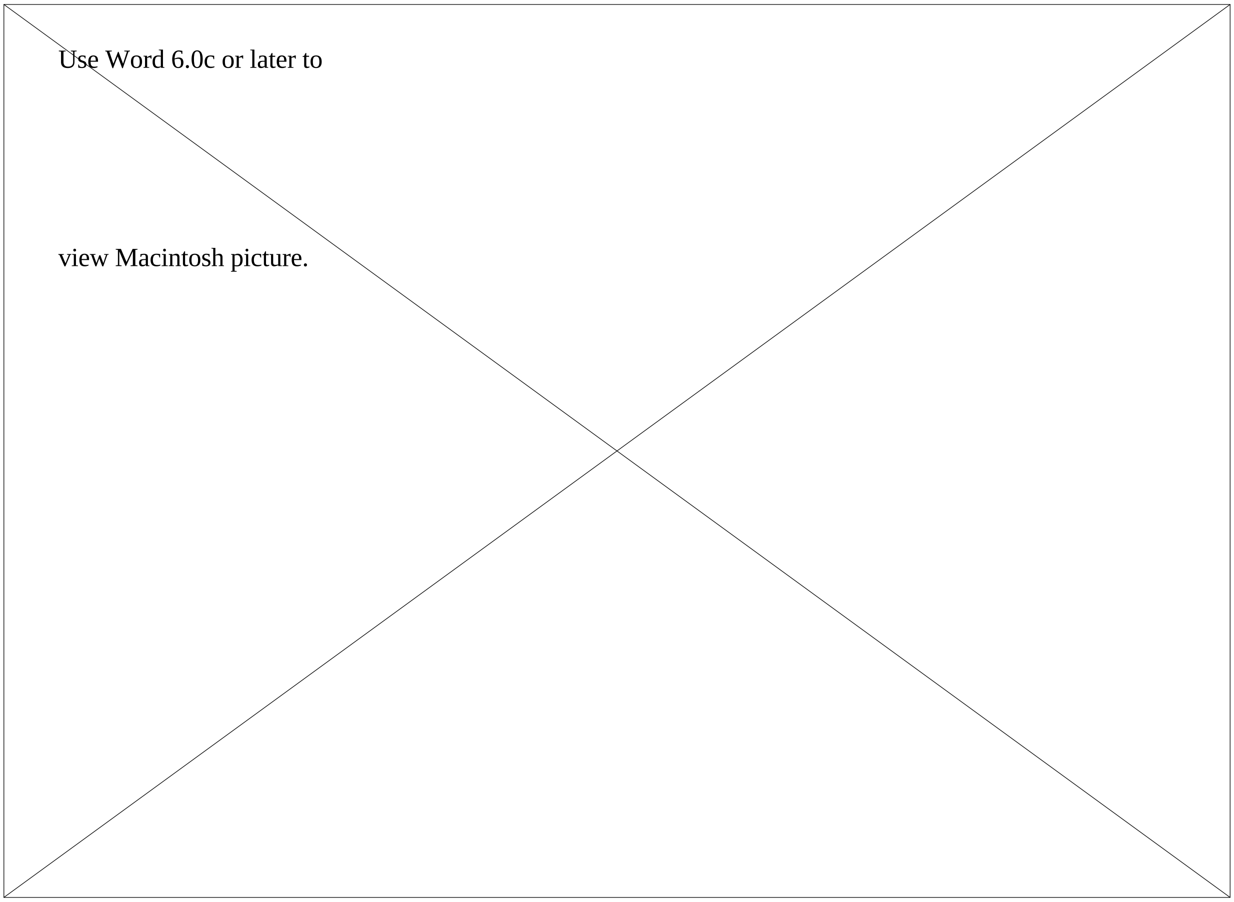

Figure 1: Coherence magnitude and phase between radial velocity u_r, azimuthal velocity v_q, and vertical displacement x as a function of vertical wavenumber for radii of 6-10 km above Fieberling Seamount. Vertical wavelengths are indicated along the upper axis. Wavelengths of 100-300 m are coherent. Radial and azimuthal velocities are 90 degrees out of phase, indicating counterclockwiseturning of the velocity vector with depth. Radial velocity and vertical displacement are 180 degrees out of phase, while azimuthal velocity and vertical displacement are 90 degrees out of phase. The phase relations involving vertical displacement are more consistent with forced damped vortex-trapped near-inertial internal waves (light stippling) than forced damped topographic waves (dark stippling).

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Figure 2: Comparison of the old (Kunze et al. 1995) model for vortex-trapped near-inertial internal waves (upper panel) and the improved model of Kunze and Boss (1997) (lowerpanel) with measurements over Fieberling Seamount (dots). The observed ranges of buoyancy frequency, core radius, core vorticity and wave vertical wavelength were used to constrain both models. The improved model curve (thick lower panel) that most closely matches the observations also has the Eulerian frequency closest (within 0.5%) of the K_1 diurnal frequency thought to force these motions.